Responses to ESP Project Gate 3 Reviewer Summary Comments

See "Document 3" for more extensive discussion of summary comments. Only the highest-level bolded summary comments are provided here.

Strategic Fit

Summarized reviewers' comments: 1) Biomass conversion technology is important, but the ESP Project should focus its development efforts on the core technologies of pretreatment, enzyme production and use, and process engineering. 2) The ESP Project should not develop technologies specific to any feedstocks, products, or byproducts.

Response: The general consensus of the review panel was that there is great value in pursuing development of core technologies in support of a sugar-based chemical and fuels industry. Such work requires selecting a model system, i.e., comprised of a model feedstock and model conversion technology components (pretreatment, cellulase enzymes, and fermentative microorganisms), upon which process integration can be performed to enable a better understanding of key process interactions to be developed, i.e., between pretreatment, enzymatic cellulose hydrolysis, and biomass sugar fermentation. While we recognize that the technology under development should not be specific to particular feedstocks, products, or coproducts, by necessity we must pick a system to work on.

For the reasons outlined above, we propose continuing to work with corn stover as the model feedstock for this project, since we believe that information developed about how to efficiently convert this material to fermentable sugars will readily translate to other lignocellulosic feedstocks, especially other agricultural residues and grassy species. [It should also be noted that corn stover is the single largest source of lignocellulosic wastes/residues currently available domestically, and as such corn stover has the largest potential as a feedstock that can support the high volume production of ethanol as a renewable alternative transportation fuel.]

We also believe that we should continue focusing on ethanol as the model sugar fermentation product. Ethanol is valuable as a commodity liquid transportation fuel, and is likely to be a flywheel co-product in the lignocellulosic biorefineries of the future. Furthermore, this work has to date been funded solely by the Biofuels Program's Ethanol Project (now Biomass Program's Sugar Platform), and the project's emphasis remains on developing and understanding sugar platform technology. In this context, the incorporation of fermentation into the project work is primarily to enable high cellulose conversion yields to be achieved using a process based on thermochemical hemicellulose hydrolysis and a hybrid enzymatic cellulose hydrolysis and biomass sugar fermentation configuration.

Work during the first year of Stage 3 is focusing most intensively on understanding pretreatment and enzymatic cellulose saccharification. Results to date indicate that cellulose conversion yields of 80-90% (the nominal target range) can only be achieved at process relevant cellulose loadings when the final stage of cellulose conversion is carried out in a simultaneous saccharification and fermentation mode. Thus, a limited amount of work to understand the compatibility of available

ethanol fermentation strains in such a process is also planned. But the clear emphasis of process development work in FY02 and beyond is on biomass pretreatment and enzymatic cellulose saccharification.

Market/Customer

Summarized reviewers' comments: According to the timeframe presented, bioethanol production will not be possible until 2005 (after the market's growth will have peaked) so bioethanol will need to compete with starch-based ethanol facilities that are part of a mature industry and will have already paid off their capital expenses.

Response: Many business risk issues exist for this project that are national/international in nature and well beyond the scope of this project to fully address. This said, the project timing is arguably overly aggressive and needs to be extended (see below) and further work needs to be done to understand the market opportunities that exist – for ethanol and other potential lignocellulose conversion coproducts – out beyond 2005. The future markets for corn and starch and the timing of the MTBE phase out remain uncertain, as do many environmental and energy security technology development drivers. Hence, there is a high degree of uncertainty about the magnitude of future increases in the demand for corn grain and ethanol. Moreover, the level of government support for potential infrastructure development needs as well as for a Stage 4 demonstration project remains unknown. Clearly, the market/customer issues are critical topics and we need to continually revisit and reassess the project direction in light of all developments.

Technical Feasibility and Risks *(related to technical development issues under the control of the ESP Project)*

Summarized reviewers' comments: The primary technical risk for this project is delivery of sufficiently low-cost cellulase enzymes by 2004 so the project can achieve its 2005 goals. *A secondary risk is to demonstrate satisfactorily robust, high performance integrated biomass hydrolysis technology (i.e., the combination of sequential pretreatment and enzymatic saccharification).* [italicized sentence added by JM]

Response: We agree with this assessment. The risk of success of enzyme development is primarily borne by the enzyme developers Genencor and Novozymes. Preliminary results show that good saccharification of pretreated corn stover can be achieved but it remains to be proven that this can be done cost effectively. We are focusing experimental work on pretreatment and enzymatic cellulose hydrolysis so that we will be able to efficiently test the lower-cost enzymes when they become available.

Competitive Advantage *(focus on economics)*

Summarized reviewers' comments: The economic analysis needs to be made more rigorous.

Response: Extensive process engineering analyses will continue in Stage 3 to develop more rigorous and defensible projections for integrated process costs.

Legal/Regulatory Compliance *and (Public Perception Issues)*

Summarized reviewers' comments: Continue life cycle analysis and increase its rigor.

Response: This is planned and underway, although support from USDA and others (e.g., ORNL) is needed to substantially extend the models rigor and breadth.

Plans *(Stage 3 plans, timelines, staffing, and budget)*

Summarized reviewers' comments: The projected resources are insufficient and the timeline too short for the project's goals.

Response: We agree and propose substantially extending the timeline for Stage 3, such that technology selection would not occur until mid-2003 or later. The objective here is to have industry perform technology selection prior to integrated process testing to support design of the Stage 4 demonstration facility. Companies or industry partnerships interested in moving the technology into Stage 4 would evaluate available information generated on pretreatment, enzymatic saccharification, fermentation, and the prospective configurations for integrating these technology components. They would then decide which option(s) to test in integrated pilot scale experiments to support the Stage 4 design work.

Commercial Opportunities *(Potential Partners)*

Summarized reviewers' comments: The project should attempt to partner with an existing industry (e.g., dry milling) and build the first plant as an add-on.

Response: As reflected by the Gate 3 review and the sugar platform colloquies that preceded it, we are actively engaging industry in project planning and our efforts to envision Stage 4. Extended work to assess the ability to partner with existing industry will be explored in Stage 3. Our approach to partnering will be based on the responses received to the letter of interest that DOE GO issued in February 2002.